FY 2010 Progress Report

Project Title: New Tools for North American Drought Prediction
Grant: NA08OAR4310622

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Highlights of Accomplishments

- Rigorously quantified the persistence of multiple, meteorological drought indicators as a function of season and location. This is a key element to developing predictions on seasonal time scales.

- Identified contributions of the initial "drought" state (may also be excessively wet, not just dry) and sea surface temperatures as a function of location and season. Focus has been on the US.

- Begun evaluation of the CFS in terms of skill assessment when a drought index (i.e., not just precipitation) is the predictand.

- Developed prototype, web-based prediction tools. These tools allow a user to: display current and past drought index conditions and obtain a map or location probabilities of exceeding user-specified index threshold.

Results and Accomplishments

We are now in year two of this 3-year project. Below is an overview of the main areas of work, including tool development, over the past year.

Observational/statistical approaches

We have quantified, for all locations and seasons, the inherent or "structural" persistence of multiple drought indicators, emphasizing the standardized precipitation index (SPI). This information serves as a) the basis for probabilistic, unconditional drought forecasts and b) a baseline for assessing what additional forecast skill dynamical models such as the CFS can provide (as a function of location, season, and lead-time).

We have developed a methodology that uses historical data and re-sampling techniques to estimate the full probability distribution (pdf) of multiple versions of the SPI to generate probabilistic forecasts at lead times of 1 month to 1 year. To date, this approach has been applied to climate division data for the US and the CPC US/Mexico precipitation analyses.

Predictability studies – Effects of SST state and initial "drought" condition

Determining drought predictors, and evaluating their efficacy has been the principal focus in this effort. We are currently conducting an observational analysis of the 115-yr contiguous U.S. precipitation data set in order to quantify predictability of the 3-month standardized precipitation index (SPI3). The potency of two predictors is being examined: a) initial SPI3, as a proxy for initial local root-zone soil moisture, and b) initial ENSO state, a known important remote source of seasonal U.S. precipitation variability. The approach considers a simple tercile representation of SPI3, for which seasonal drought conditions are assumed to exist when the SPI3 index value resides in the lower tercile of the historical distribution. As such, there exists a 33% climatological probability of drought, and the question being addressed is how the aforementioned initial conditions either enhance or diminish future (0-lead) seasonal drought probabilities.

• *This research indicates that both initial drought conditions and initial ENSO conditions exert appreciable control of future drought risks.*

The probability for drought increases by 10% (i.e., total drought chance is 43%) across large areas of the Great Plains and Interior West when initial SPI3 conditions are in the lower tercile, in the absence of any ENSO forcing (Fig. 1, top left panel). With the further condition that the initial ocean state is in a La Niña (Fig. 1, middle panel), future (0-lead) drought probabilities are enhanced in the Southwest, the Great Plains, and deep South regardless of the initial SPI3 condition. However, it is clear that the areal extent of enhanced drought risk (i.e., greater than 33% probabilities), and the probability amplitudes are greatly elevated when initial conditions are dry, rather than wet. Analogously, when the initial ocean state is during El Niño (Fig. 1, bottom), future

drought probabilities are greatly reduced over those same regions when initial soil conditions are wet, rather than dry. We are currently determining the robustness of these results to observational data uncertainties, and are examining the physical basis for drought predictability using climate models that incorporate various levels of ocean and land coupling.

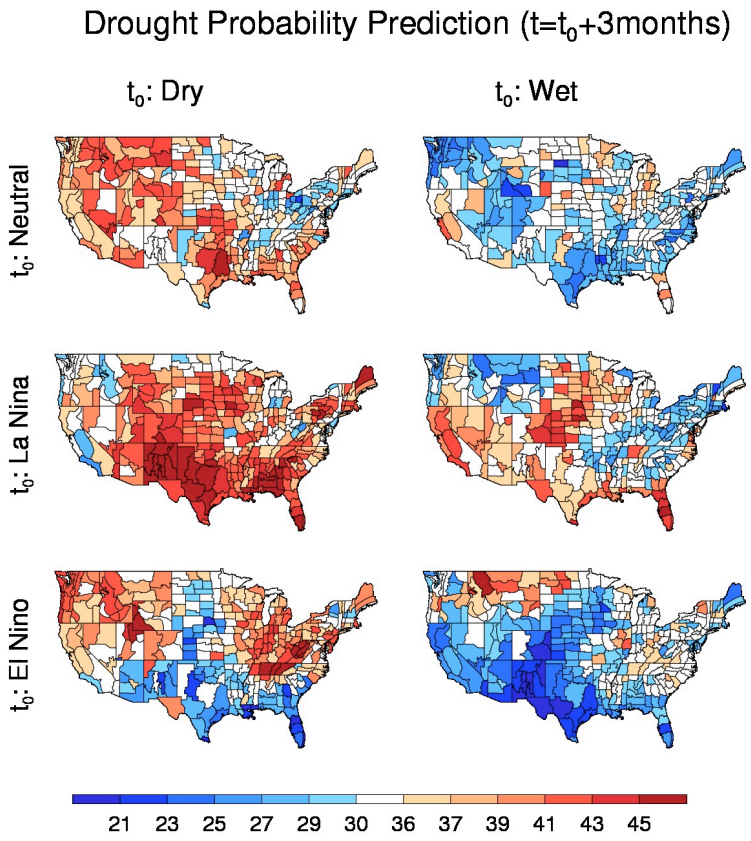

Figure 1. *The 0-lead prediction of probabilities of 3-month drought (as indicated by the 3-month standardized precipitation index, SPI3) associated with various combinations of initial conditions (t0): Local Dry (lower tercile SPI3; left) and local Wet (upper tercile SPI3; right), and ENSO state being either neutral (top), La Niña (middle), or El Niño (bottom). A prediction of climatological probability would be 33% and is denoted by white regions, whereas a prediction of enhanced (suppressed) drought risk is denoted by red (blue) shades. The U.S. precipitation data is from NCDC's climate division data, and SSTs are based on the Hurrrell et al. (2008) data each for the period 1896-2009.*

Modeling studies using the CFS

This is work has primarily involved (a) an analysis of the prediction skill for the SPI3 based on the Climate Forecast System (CFS) hindcasts from 1981-2006, (b) assessment of the skill of real-time forecasts from 2005-present, and (c) an analysis of the dependence in the SPI prediction skill on the soil-moisture initial conditions, and slowly varying sea surface temperature (SST) boundary forcing. The analysis complements the

efforts using statistical methods and other dynamical models. During the past year, this effort focused on the analysis of skill for the SPI3 based on the CFS hindcasts. Tasks completed include (a) assembling the necessary datasets from the CFS hindcast archives, and (b) assessing the skill of hindcasts for the SPI3. An example of skill for SPI3 for January (top panel) and July (bottom panel) CFS hindcasts is shown in Figure 2. Skill for lead time of 2 month prediction, for example, CFS forecasts starting from the month of January and predicting the SPI3 for the April, are based entirely on the precipitation predicted by the CFS, and some prediction skill in the SW US (for January initial conditions) and in the NE US (for the July initial conditions) is documented. We plan to continue along with this approach during the coming year.

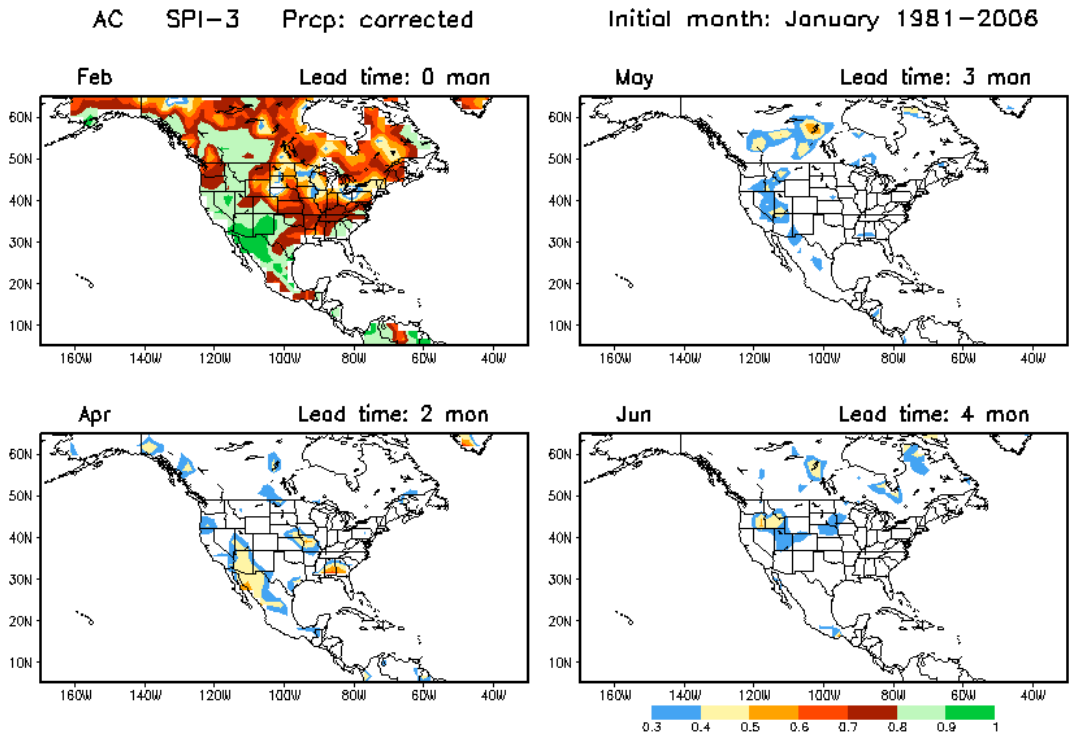

Figure 2 *Correlation between the forecast SPI-3 based on precipitation forecasts from the CFS and observations. Above panels are for January start times/initial SPI-3 conditions. The panels below are for July start times/initial SPI-3 conditions.*

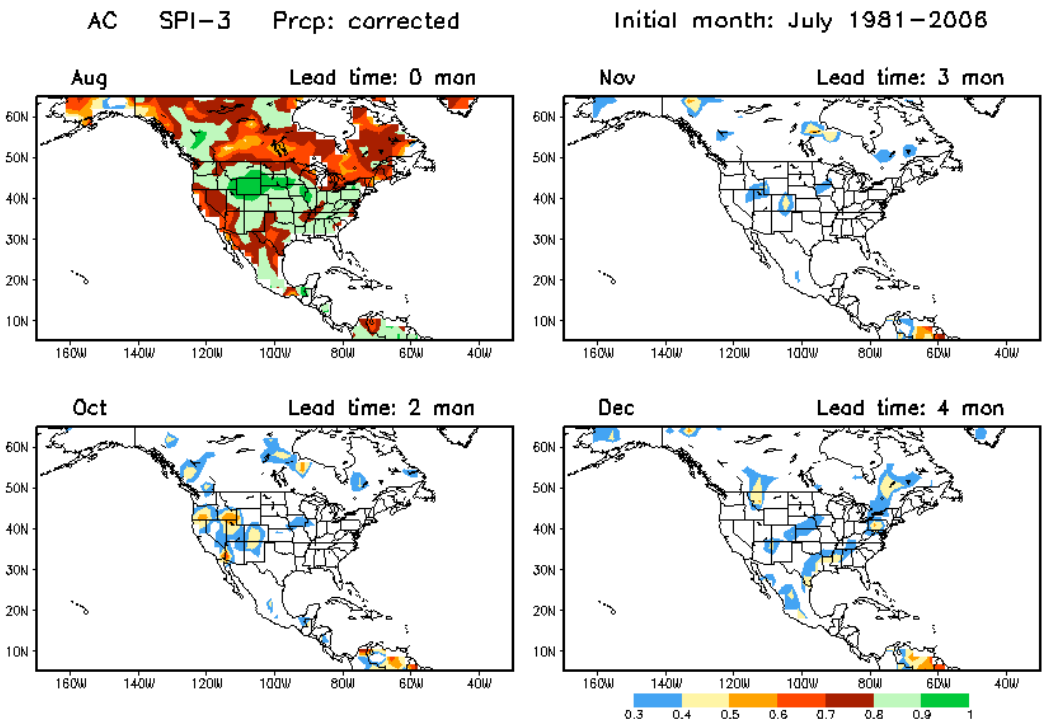

Figure 2 (cont'd) *As above but for July start times/initial SPI-3 conditions.*

Tools developed

A prototype, web-based tool for assessing the initial and forecast drought state based on US climate division data is in development (a graphic output from the tool is provided below in Figure 3). Currently this tool propagates the initial drought condition forward in time by using synthetic time series (> 5,000 years) of precipitation generated from past, observed behavior. This represents a "fallback" prediction tool that can generate objective probability estimates for several drought indicators at a future time even in locations and seasons where there is no predictive skill from dynamical models, for example. The next stage in developing this tool is to incorporate seasonal climate predictions of precipitation from the IRI multi-model ensemble and the CFS.

A prototype tool similar to above but based on gridded precipitation products is also under development (Figure 4). Both of these tools allow the user to zoom to a region of interest, select the drought indictor desired (currently different versions of the SPI), select the lead time for the forecast and the threshold index value to see a quantified measure of the probability of exceedance. Users can also display the "best estimate" SPI forecast value and select any grid point (or climate division) with a mouse and see time series of past-to-current drought indicator values and other, forecast, information.

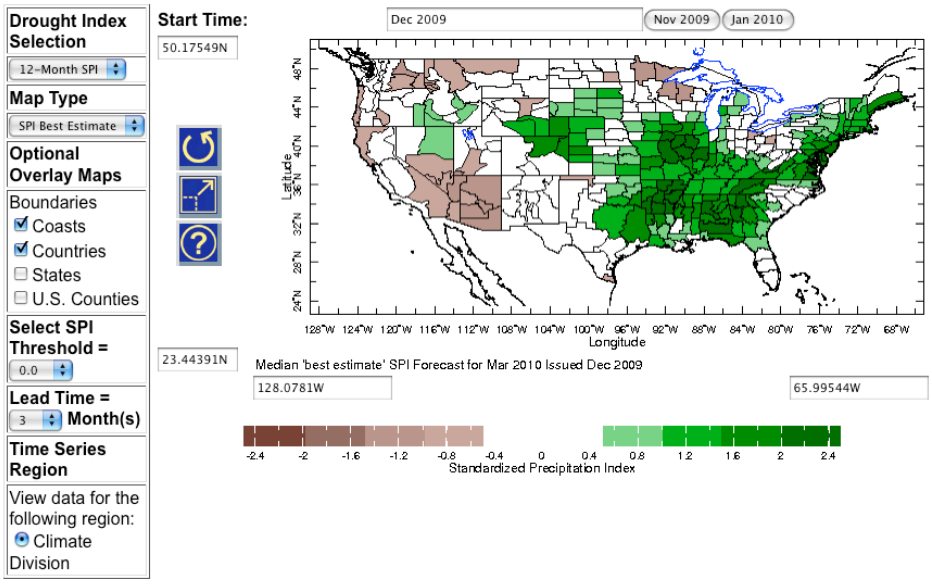

Figure 3. *Sample display from a prototype drought prediction tool which utilizes US climate division data. The map above shows the "best estimate" (median value of the probability distribution) of the SPI-12 for a 3-month lead forecast made in December 2009. Users can select other SPI indices and click on any climate division to get a time series of past index variations, comparison of current conditions with past years, and other, forecast, information.*

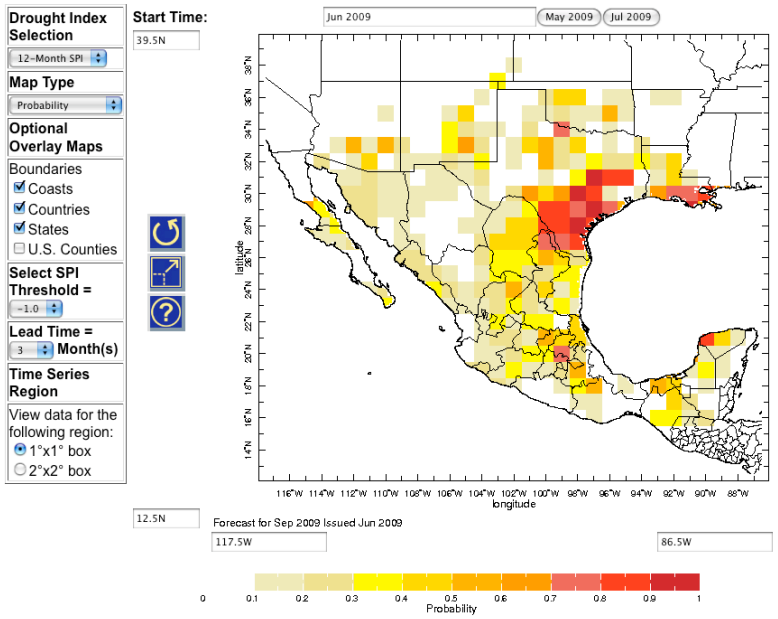

Figure 4. *The map above shows a sample display of the unconditional probability of exceeding a selected threshold value (-1.0) of the 12-month SPI for a lead-time of 3 months from a starting time of June 2009. Reddened areas highlight substantially enhanced probability. A similar tool is under development that will produce conditional forecast information based outputs from the IRI MME and the CFS.*

Publications

- Lyon, B. and co-authors, 2010: Quantifying the roles of persistence and sea surface temperatures in the prediction of meteorological drought. *Journal of Hydrometeorology* (in prep.)

Presentations

Lyon, B., and M.A. Bell, 2010: Assessing Sources of Skill in Predictions of Meteorological Drought. *90th American Meteorological Society Annual Meeting*, Atlanta, GA, 18 January 2010.

Lyon, B., 2009: Time Scales of Climate Variability and Climate Risk Management. IMTA, Cuernavaca, Mexico, 24 July 2009. (INVITED)

Lyon, B., 2009: IRI Seasonal Forecasts: Uses, Improvements, and Moving Beyond the Seasonal Time Scale. *2nd Workshop on Variability and Climate Change in the West Coast of North America*. IMTA, Cuernavaca, Mexico, 22 July 2009. (INVITED)

Future Work

- Document (in the form of peer-reviewed journal articles) the contributions of persistence, SST, and "drought" initial condition on the predictability of meteorological drought indices.

- Continue work with the CFS to evaluate its skill and adjust bias errors in the prediction of meteorological drought indices

- Continue the development of the web-based statistical analysis tools

- Develop an additional web-based forecast tool that uses the IRI multi-model ensemble seasonal forecasts to predict meteorological drought indicators

- Compare skill of the IRI MME forecasts with the CFS

- Publish results in peer-reviewed journal articles

Budget for the coming year

IRI: ≈ $51,339
CPC ≈ $32,000(est.)
ESRL ≈ $74,000 (est.)